A REVIEW OF CLOSED-LOOP SUPPLY CHAIN AND REVERSE LOGISTICS MODELS

BY

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Abstract

Closed-loop supply chains (CLSC) have been studied extensively in the literature due to the cost and environmental optimization in operations. CLSC consists of forward and reverse supply chains. This paper reviews the literature of CLSC networks. 223 peer-reviewed articles that have been published in international journals from 1997 to 2020 are gathered and analysed. The aim is to answer the following main questions: (i) What is the problem domain in CLSC? (ii) Which techniques are utilized frequently in CLSC? (iii) What elements, variables, and objectives are the main focus in the field? (iv) What are the gaps in the literature? After reviewing the literature, observations are provided. Finally, the evaluations conclude suggested improvements and potential future directions in the research field.

Keywords: Supply chain management (SCM); Closed-loop supply chain (CLSC); Reverse logistics (RL); Uncertainty; Game theory

Table of contents

List of Tables

List of Figures

Introduction

Many researchers have studies reverse logistics (RL). Fleischmann et al., 1997 defined the range of reverse logistics activities from the return of used products by customers all the way to usable final products in markets. In a study done by Guide and Wassenhove, 2009, it was estimated that the returned products' value in dollars for one retailer can exceed nine figures. (Guide and Wassenhove, 2009)). After products are returned, recovery activities which include product acquisition, disposition, repair, remarketing, and remanufacturing are performed. (Guide and Wassenhove, 2009).

The main objective of RL is to optimize the economic as well as the environmental values from returned products. On the other hand, forward (traditional) logistics is only focused on providing products for customers, (Akçalı and Çetinkaya, 2010). Closed-loop supply chains (CLSCs) are the result of the integration of forward and reverse logistics networks and hence they are usually more complex than the traditional supply chains (Guide and Wassenhove, 2009; Melo et al., 2009). A common example of a CLSC network is paper recycling (Fleischmann et al., 1997). There are some major decisions in CLSC configuration such as: Which facilities (e.g. collection centers) are open? What products and parts should be ordered from external suppliers and which suppliers are selected? How many products and parts are there in each part of networks? In which periods the products should be ordered? Fig. 1 demonstrates a general CLSC network.

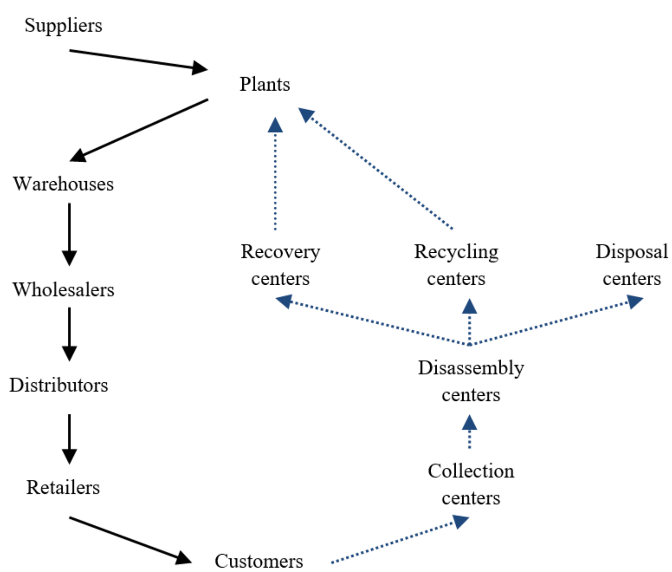

Figure 1. A general closed-loop supply chain network
(forward supply chain ⟶, reverse supply chain ⋯▸)

Compared to previous surveys, this literature review has two unique features: First, although most of literature reviews examined reverse logistics, we focus on CLSC networks and related mathematical models. Secondly, not only we consider deterministic models, but also special attention is made to analyze uncertain and game-theoretic models. Based on 223 peer-reviewed international journals three questions are examined including: (i) What is the problem domain in CLSC? (ii) Which techniques are utilized in CLSCs frequently? (iii) What are the gaps in the literature? In this paper, we analyze the quantitative papers that utilize operations research to configure CLSC networks. It is noticeable that we do not categorize papers related to performance measurement or alternative selection in CLSC.

The remainder of the paper is structured as follows: In Section 2, we introduce our taxonomy and we classify the literature. In Section 3, observations and recommendations are discussed. Finally, Section 4 focuses on conclusions and future research.

Taxonomy

This literature review is based on two dimensions: problem domain (conceptual classification), and operations research techniques (mathematical-based classification). The taxonomy enables us to provide in depth analysis of CLSC papers.

Problem domain

The problem domain comprises four sections: literature reviews (LR), deterministic optimization models (DO), uncertain optimization models (UO), and game-theoretic models (GT). The main difference between optimization and game-theoretic models is the number of decision-makers. In game-theoretic models, different players may have different objectives and they try to optimize their objective functions. Therefore, they can cooperate or compete. On the other hand, optimization models are one person games and the problem is considered from viewpoint of one decision-maker (player). The references are classified in Table 1.

Table 1. Classification of the references based on problem domain

Problem domain	References
Literature reviews (LR)	Fleischmann et al. (1997), Gungor and Gupta (1999), Linton et al. (2007), Rubio et al. (2008), Sasikumar and Kannan (2008a), Sasikumar and Kannan (2008b), Chanintrakul et al. (2009), Guide and Wassenhove (2009), Jamsa (2009), Melo et al. (2009), Pokharel and Mutha (2009), Ilgin and Gupta (2010), Akçalı and Çetinkaya (2010), Lambert et al. (2011), Hassini et al. (2012), Souza (2012), Govindan et al. (2013), Stindt and Sahamie (2012), Krikke et al. (2013), Bhakthavatchalam et al. (2015), Govindan et al. (2015), Gurtu et al. (2015), Schenkel (2015), Battini et al. (2016), Cannella et al. (2016), Jena and Sarmah (2016), Battini et al. (2017), Gaur et al. (2017), Govindan and Soleimani (2017), Krapp and Kraus (2017), Wang et al. (2017), Braz et al. (2018), Coenen et al. (2018), Gaur and Mani (2018), Islam and Huda (2018), Kazemi et al. (2018), Lapko et al. (2018), Shekarian (2020)
Deterministic optimization models (DO)	Jayaraman et al. (1999), Fleischmann et al. (2009), Hu et al..(2002), Beamon and Fernandes (2004), Sheu et al. (2005), Salema et al. (2006), Ahluwalia and Nema (2006), Jayaraman (2006), Kim et al. (2006), Min et al. (2006a), Min et al. (2006b), Schultmann et al. (2006), Ko and Evans (2007), Lashkari and Duan (2007), Lu and Bostel (2007), Sharma et al. (2007), Sheu (2007), Üster et al. (2007), Chung et al. (2008), Demirel and Gökçen (2008), Du and Evans (2008), Lashkari and Zhang (2014), Min and Ko (2008), Pati et al. (2008), Sheu (2008), Tang et al. (2008), Zhou and Wang (2008), Zuidwijk and Krikke (2008), Cruz-Rivera and Ertel (2009), Gupta and Evans (2009), Kannan et al. (2008), Lee and Chan (2009), Lee et al. (2009), Mutha and Pokharel (2009), Neto et al. (2009), Pan et al. (2009), Xanthopoulos and Iakovou (2009), Achillas et al. (2010), Easwaran and Üster (2010), Fröhling et al. (2010), Kannan et al. (2010), Pishvaee et al. (2010), Pishvaee et al. (2009b), Salema et al. (2010), Sasikumar et al. (2010), Wang and Hsu (2010a), Yuan and Gao (2009), Gomes et al. (2011), Krikke (2011), Kumar and Chan (2011), Paksoy et al. (2011), Alumur et al. (2012), Amin and Zhang (2011), Assavapokee and Wongthatsanekorn (2012), Das and Chowdhury (2012), Dat et al. (2012), Kannan et al. (2012), Özkır and Başlıgil (2012), Lundin (2012), Zhang et al. (2012), Özceylan and Paksoy (2013a), Eskandarpour et al. (2013), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Devika et al. (2014), Özceylan et al. (2014), Diabat et al. (2015), Ramezani et al. (2014a), Asad et al. (2019), Chen et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Ghayebloo et al. (2015), Kaya and Urek (2016), Kim and Jeong (2016), Nallusamy et al. (2018), Papen and Amin (2018), Pazhani and A (2018), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018), Ramezani and Jafari (2018), Rezaee et al. (2016), Roghanian and Cheraghalipour (2019), Sherif et al. (2019), Tokhmehchi et al. (2015), Wu et al. (2019)

Uncertain optimization models (UO)	Inderfurth (2005), Lieckens and Vandaele (2007), Listeş (2007), Salema et al. (2007), Vlachos et al. (2007), Li et al. (2008), Selim and Ozkarahan (2006), Francas and Minner (2009), Ketzenberg (2009), Lee and Dong (2009), Pishvaee et al. (2009a), El-Sayed et al. (2010), Kara and Onut (2010), Pishvaee and Torabi (2010), Qin and Ji (2010), Shi et al. (2010), Wang and Hsu (2010b), Georgiadis et al. (2011), Pishvaee et al. (2011), Rouf and Zhang (2011), Sasikumar and Haq (2011), Shi et al. (2011a), Shi et al. (2011b), Zhang et al. (2011), Abdallah et al. (2011), Amin and Zhang (2012), Mitra (2012), Amin and Zhang (2013a), Amin and Zhang (2013b), Hasani et al. (2012), Vahdani et al. (2012a), Vahdani et al. (2012b), Zeballos et al. (2012), Ramezani et al. (2013), Özkır and Başlıgil (2013), Vahdani et al. (2013a), Cardoso et al. (2013), Ramezani et al. (2012), Vahdani et al. (2013b), Wang and Huang (2013), Amin and Zhang (2014), Demirel et al. (2014), Hatefi and Jolai (2014), Mirakhorli (2013), Özceylan and Paksoy (2013b), Ramezani et al. (2014b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin et al. (2017), Amin and Baki (2017), Chen et al. (2018), Fazli-Khalaf et al. (2017), Ghahremani-Nahr et al. (2019), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Hamdouch et al. (2016), Kai et al. (2016), Kim et al. (2018), Talaei et al. (2016), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Vahdani and Mohammadi (2015), Yavari and Geraeli (2019), Tosarkani et al. (2019)
Game-theoretic models (GT) (33)	Majumder and Groenevelt (2009), Savaskan et al. (2004), Debo et al. (2005), Heese et al. (2005), Hammond and Beullens (2007), Webster and Mitra (2007), Atasu et al. (2008), Mitra and Webster (2008), Yang et al. (2009), Chen and Bell (2011), Chen (2011), Chen and Chang (2012), Hong and Yeh (2012), Qiang et al. (2013), Guo and Ma (2013), Chen (2014), Choi et al. (2013), Zhou et al. (2013), Feng et al. (2014), Giovanni and Zaccour (2014), Ma and Wang (2014), Wei et al. (2015), Huang et al. (2013), Wei and Zhao (2013), Esmaeili et al. (2015), Aydin et al. (2016), Ghobadi and Esmaeili (2018), Huang and Wang (2017), Patne et al. (2018), De Giovanni and Zaccour (2019), Wang et al. (2019), Yang and Xu (2019), Zhao and Sun (2019)

Literature reviews

In this section, we mention some literature reviews that have been written about CLSC and reverse logistics. Fleischmann et al. (1997) provided a survey for reverse logistics context. The study categorized CLSC into three divisions: production planning, inventory control, and distribution planning. In addition, uncertainty in reuse activities was emphasized. And it was mentioned that remanufacturing and reuse usually are activities in closed-loop systems, but recycling may often happen in open-loops. In a different paper, Sasikumar and Kannan (2008b) studied five aspects of the research in reverse logistics: decision-making models, network design, third-parties, vehicle routing problem, and the role of IT (information technology). An interesting conceptual framework for the literature in reverse logistics was presented by Lambert et al. (2011), the study also examined various industrial case studies. Govindan et al. (2013) concluded there are some future opportunities for multi-echelon supply chains after reviewing applications of contracts like buyback and two-part tariff in forward and reverse supply chain models. Cannella et al. (2016) took a different approach in analyzing closed loop supply chains as the focus of the study was the performance aspect of CLSCs and the effects that different elements have on it. It was found that for all types of structures and market demands, CLSCs have a higher order and inventory stability than traditional forward supply chains. In an important investigation, Gaur and Mani (2018) found that what drives CLSCs internally are seven factors: business opportunities, regulations, consumers as consumers, consumers as suppliers, media, NGO, and competitors.

In the area of supply chain management, papers related to facility location models were reviewed by Melo et al. (2009). The study also addressed reverse logistics articles. The RL literature have been categorized in two groups: recovery networks and closed-loop networks. Some literature (e.g., Battini et al., 2017) targeted CLSC papers published in specific journals for their review. The study provided a summary of an International Journal of Production Economics (IJPE) special issue discussing different aspects of CLSCs. The summary categorized the 24 published papers in the special issue into six topics and a thorough analysis of each topic was discussed. Govindan and Soleimani (2017) studied 83 Journal of Cleaner Production (JCP) papers in the period (2001-2014), in the area of CLSCs and reverse logistics. The study analyzed and categorized the papers in accordance to their main subject, industry, decision-making level, country, and citations. As for the International Journal of Production Research (IJPR), Kazemi et al. (2018) reviewed and classified 94 of their CLSC papers in the period (2000-2017) according to their main-themes, and whether a mathematical model was used or not. Other literature review papers considered a different scope. To address the challenges of approaching deep uncertainty and dynamic complexity, Coenen et al. (2018) analyzed 64 articles based on sources and types of uncertainty and complexity. Shekarian (2020) analyzed 215 papers that used game theory in CLSCs modelling. The study presents the gaps, current focus, and direction of the literature for certain factors affecting CLSC models.

Core acquisition is one of the main factors that influence the flow of CLSCs. The usefulness of developing pricing models for acquiring used products was emphasized by Pokharel and Mutha (2009). One of the methods of core acquisition in CLSCs is by product returns. Guide and Wassenhove (2009) classified returns in CLSCs into three types: commercial, end-of-use, and end-of life. Krikke et al. (2013) investigated different types of returns in CLSCs by conducting a survey among third party service providers. The study provided some propositions about characteristics of returns such as volumes and values of returns. It is also mentioned that there is a lack of articles that consider stochastic demand of new products and supply of used products. Moreover, Jena and Sarmah (2016) presented, using content analysis method, 90 CLSC literature in the period (2000-2014) related to remanufacturing; with a focus on acquisition management of returned items. Gaur et al. (2017) developed a framework targeting technical issues found in CLSCs regarding core acquisition. The paper discussed consumer disposition behavior and found that it is affected by four main factors: psychological, product related, situational, and cultural. To further clarify the concept of returns a state-of-the-art review was conducted by Krapp and Kraus (2017) where the growth of CLSCs was emphasized as more regulations mandate the reuse of products.

After returning products, they can be recovered in many ways. Gungor and Gupta (1999) reviewed papers that discuss product recovery and manufacturing from an environmentally conscious viewpoint. The study divided the recovery processes into recycling and remanufacturing. Moreover, Sasikumar and Kannan (2008a) provided a useful classification of product recovery options including direct reuse, recycling, remanufacturing, and repair. Examining the effects of demand of manufactured products on remanufactured products was proposed as a future research direction by Akçalı and Çetinkaya (2010). By using the framework of Gungor and Gupta (1999), Ilgin and Gupta (2010) presented a literature review that discussed aspects of product acquisition management. The study also touched on product and network design, transportation optimization, selection of suppliers, performance measurement, and marketing-related issues. Souza (2012) targeted certain issues, mainly strategic and tactical, with CLSC literature. And it was concluded that most CLSC research is focused on remanufacturing rather than recycling and that more literature should be focused on green CLSC. Various types of models in the literature were evaluated by Bhakthavatchalam et al. (2015) to shed the light on certain CLSC issues found mainly in remanufactured products.

Linton et al. (2007) provided a review for papers of supply chains in sustainability context with a focus on environmental issues. The study also discussed recovery processes and the product from an end-of-life perspective. CLSCs are a major part of sustainable supply chains and green supply chains. This was shown when numerous CLSC papers were mentioned when Hassini et al. (2012) categorized the literature of sustainable supply chains. Moreover, Gurtu et al. (2015) provided an extensive peer-reviewed literature analysis of the keywords used in green supply chain management. It was found that the most used keyword in the literature of GSCM is “Reverse logistics” (48.1%) followed by “Green supply chains” (18.1%) and “closed-loop supply chains” (17.3%). Other statistics for used keywords were provided that showed similar trends. From a humanitarian perspective, Battini et al. (2016) studied CLSCs while considering the network cost and performance. When studying the bullwhip effect in CLSC, Braz et al. (2018) concluded that its causes for CLSCs do not vary from those of forward supply chains, and that adopting a CLSC can lead to increasing the environmental performance of the supply chain. Islam and Huda (2018) presented an extensive literature analysis of 157 papers in the period (1999-2017) in the area of E-waste in CLSCs and reverse logistics. A variety of characteristics were considered for the categorization of the papers. Future works addressing the research gaps were proposed. Moreover, the importance of CLSCs in the sustainability of Critical raw materials (CRMs) was emphasized by Lapko et al. (2018).

The future of CLSC research seems very promising as many directions and gaps were proposed by different research papers. Rubio et al. (2008) mentioned that more research is necessary for strategic factors (e.g. marketing, competition) because most authors have only considered tactical and operational factors. Jamsa (2009) reviewed 45 papers in the area of reverse logistics. It was observed that only a few papers have considered case studies. In another direction, Chanintrakul et al. (2009) provided a reverse logistics literature review for papers published in the period (2000-2008). The paper discussed six sections: the impact of uncertainty, stochastic models, the transportation impact, a multi-agent character analysis, a RL network of hazardous waste, and simulation models. The study stated that developing multi-objective, multi-period models can be subject of future works. Stindt and Sahamie (2012) categorized the field of CLSC in the process industry into surveys, quantitative research papers, qualitative research papers, qualitative case studies, and quantitative case studies. They suggested more interdisciplinary research can be done. Different proposals on future directions regarding new methodologies, the inclusion of different environmental objectives, new sources of uncertainty, and modification of nondeterministic models were proposed by Govindan et al. (2015). In another study for the economic, environmental, information, and customer value creation in CLSCs by Schenkel (2015), it was found that there are close to no papers that study the value created from the association of both forward and reverse supply chains. Wang et al. (2017) provided an exhaustive analysis of 912 published studies on reverse logistics in the period (1992-2015) to examine the references and trends for future research and direction in the field of reverse logistics.

Deterministic optimization models

In this section, we provide descriptions for some of the deterministic optimization CLSC models. Others are just mentioned in the following two Tables. The references have been categorized based on multiple elements (e.g. products, facilities) in Table 2. Some authors considered multiple parts and products. The difference between products and parts is that each product can be disassembles to multiple parts. Table 3 shows a classification according to the optimization constraints. We do not mention network constraints in the Table. Network constraints are defined as balancing of flows between nodes of networks.

Jayaraman et al. (1999) provided an optimization model for a closed-loop logistics network. They minimised total cost by a mixed-integer linear programming model. Then, the model has been solved by a software (GAMS). Kim et al. (2006) configured a generic reverse logistics network by maximizing total cost saving. They supposed multiple products, parts, and most importantly time periods. In other words, they considered inventory parameters. Schultmann et al. (2006) investigated different design options for a real CLSC network. They applied vehicle routing planning.

Chung et al. (2008) examined an inventory system including both forward and reverse flows. The objective function (profit) has been maximized. It is noticeable that the inventory system distinguishes the paper from other papers in this field. Pati et al. (2008) examined a paper recycling system by a mathematical model. The paper uses goal programming as a new technique in this field. They defined three objective functions for a case study. Xanthopoulos and Iakovou (2009) developed a RL model with two phases. In the first phase, a decision making-model is used to identify related components. While in the second, configuration of the network has been done by applying a multi-period optimization. Yuan and Gao (2009) developed the mathematical model of Chung et al. (2008) by applying new inventory policies and they compared the results.

After extending a forward logistic model to a RL model, Fleischmann et al. (2009) discussed their differences and provided further extensions such as integrating both forward and reverse logistics models. Pishvaee et al. (2010) proposed a multi-objective model for a CLSC network. They developed a memetic algorithm for the model. Kumar and Chan (2011) developed an optimization model that applied RFID technology in a CLSC network. Superiority search and optimization algorithm were used to solve the model. Lundin (2012) developed a multi-period optimization model for a cash supply chain. The CLSC includes a central bank and groups of private companies. This feature distinguishes the paper from other papers in this field. They examined the impacts of design changes.

Chen et al. (2014) introduced a two-stage genetic algorithm (GA) CLSC model wthich considered delivery activities of different recycled materials and the quality of the recycled products. The model was tested with a location allocation study case of cartridge recycling in Hong Kong. Ghayebloo et al. (2015) developed a five-echelon bi-objective CLSC model that aims to maximize profit and greenness. The study also examines the effect of reliability and greenness of parts and products on the network design of the reverse loop. Pazhani and A (2018) focused on minimizing the energy footprint while maximizing the supply chain model by developing a four-stage CLSC model while considering commercial returns. Asad et al. (2019) developed two mathematical models for different raw material replenishment strategies (Multi-to-One and One-to-Multi) to optimize raw material procurement and finished product shipping decisions. Sherif et al. (2019) proposed a green CLSC network with societal constraints (GCLSCN-SC) for the battery industry. A comparison of different scenarios between the current model and the proposed model was provided.

Table 2. **Classification of deterministic optimization models based on multiple elements**

Multiple elements	References
Parts	Kim et al. (2006), Sharma et al. (2007), Zuidwijk and Krikke (2008), Gupta and Evans (2009), Lee et al. (2009), Xanthopoulos and Iakovou (2009), Fröhling et al. (2010), Kannan et al. (2010), Kumar and Chan (2011), Alumur et al. (2012), Amin and Zhang (2011), Das and Chowdhury (2012), Dat et al. (2012), Özkır and Başlıgil (2012), Özceylan and Paksoy (2013a), Eskandarpour et al. (2013), Chen et al. (2014), Ghayebloo et al. (2015), Ghobadi and Esmaeili (2018), Rad and Nahavandi (2018), Rezaee et al. (2016)
Products	Jayaraman et al. (1999), Hu et al. (2002), Ko and Evans (2007), Salema et al. (2006), Ahluwalia and Nema (2006), Jayaraman (2006), Kim et al. (2006), Lu and Bostel (2007), Sharma et al. (2007), Sheu (2007), Üster et al. (2007), Demirel and Gökçen (2008), Du and Evans (2008), Lashkari and Zhang (2014), Min and Ko (2008), Pati et al. (2008), Tang et al. (2008), Zuidwijk and Krikke (2008), Gupta and Evans (2009), Kannan et al. (2008), Lee et al. (2009), Neto et al. (2009), Xanthopoulos and Iakovou (2009), Achillas et al. (2010), Easwaran and Üster (2010), Kannan et al. (2010), Salema et al. (2010), Gomes et al. (2011), Kumar and Chan (2011), Alumur et al. (2012), Amin and Zhang (2011), Assavapokee and Wongthatsanekorn (2012), Das and Chowdhury (2012), Dat et al. (2012), Özkır and Başlıgil (2012), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Devika et al. (2014), Asad et al. (2019), Ghayebloo et al. (2015), Kim and Jeong (2016), Nallusamy et al. (2018), Papen and Amin (2018), Rad and Nahavandi (2018), Ramezani and Jafari (2018), Rezaee et al. (2016), Sherif et al. (2019), Tokhmehchi et al. (2015),
Modules	Jayaraman (2006), Zuidwijk and Krikke (2008), Das and Chowdhury (2012)
Suppliers	Lashkari and Zhang (2014), Pati et al. (2008), Sheu (2008), Gupta and Evans (2009), Mutha and Pokharel (2009), Fröhling et al. (2010), Kannan et al. (2010), Wang and Hsu (2010a), Lashkari and Duan (2007), Paksoy et al. (2011), Amin and Zhang (2011), Das and Chowdhury (2012), Özceylan and Paksoy (2013a), Eskandarpour et al. (2013), Soleimani et al. (2013a), Devika et al. (2014), Özceylan et al. (2014), Ramezani et al. (2014a), Asad et al. (2019), Chen et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Ghayebloo et al. (2015), Ghobadi and Esmaeili (2018), Papen and Amin (2018), Pazhani and A (2018), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018), Ramezani and Jafari (2018), Rezaee et al. (2016), Roghanian and Cheraghalipour (2019)
Periods	Hu et al. (2002), Sheu et al. (2005), Jayaraman (2006), Kim et al. (2006), Min et al. (2006b), Ko and Evans (2007), Sheu (2007), Sharma et al. (2007), Lashkari and Zhang (2014), Min and Ko (2008), Sheu (2008), Gupta and Evans (2009), Kannan et al. (2008), Pan et al. (2009), Xanthopoulos and Iakovou (2009), Kannan et al. (2010), Salema et al. (2010), Sasikumar et al. (2010), Gomes et al. (2011), Kumar and Chan (2011), Alumur et al. (2012), Assavapokee and Wongthatsanekorn (2012), Özkır and Başlıgil (2012), Lundin (2012), Zhang et al. (2012), Özceylan and Paksoy (2013a), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Özceylan et al. (2014), Ramezani et al. (2014a), Kim and Jeong (2016), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018), Ramezani and Jafari (2018), Sherif et al. (2019), Wu et al. (2019)
Scenarios	Demirel and Gökçen (2008), Cruz-Rivera and Ertel (2009), Das and Chowdhury (2012), Fathollahi-Fard and Hajiaghaei-Keshteli (2018)
Plants (factories, manufacturers)	Fleischmann et al. (2009), Beamon and Fernandes (2004), Salema et al. (2006), Ko and Evans (2007), Lashkari and Duan (2007), Lu and Bostel (2007), Üster et al. (2007), Demirel and Gökçen (2008), Du and Evans (2008), Lashkari and Zhang (2014), Min and Ko (2008), Sheu (2008), Zhou and Wang (2008), Kannan et al. (2008), Mutha and Pokharel (2009), Fröhling et al. (2010), Kannan et al. (2010), Salema et al. (2010), Sasikumar et al. (2010), Wang and Hsu (2010a), Paksoy et al. (2011), Alumur et al. (2012), Das and Chowdhury (2012), Özkır and Başlıgil (2012), Özceylan and Paksoy (2013a), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Ramezani et al. (2014a), Asad et al. (2019), Chen et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Nallusamy et al. (2018), Papen and Amin (2018), Pazhani and A (2018), Pourjavad and Mayorga (2018), Sherif et al. (2019), Tokhmehchi et al. (2015), Wu et al. (2019)

Markets (customers)	Jayaraman et al. (1999), Fleischmann et al. (2009), Sheu et al. (2005), Salema et al. (2006), Min et al. (2006a), Min et al. (2006b), Ko and Evans (2007), Lashkari and Duan (2007), Lu and Bostel (2007), Sharma et al. (2007), Demirel and Gökçen (2008), Min and Ko (2008), Pati et al. (2008), Zhou and Wang (2008), Cruz-Rivera and Ertel (2009), Lee and Chan (2009), Mutha and Pokharel (2009), Pishvaee et al. (2010), Pishvaee et al. (2009b), Salema et al. (2010), Sasikumar et al. (2010), Wang and Hsu (2010a), Krikke (2011), Paksoy et al. (2011), Assavapokee and Wongthatsanekorn (2012), Das and Chowdhury (2012), Dat et al. (2012), Kannan et al. (2012), Özkır and Başlıgil (2012), Özceylan and Paksoy (2013a), Eskandarpour et al. (2013), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Devika et al. (2014), Özceylan et al. (2014), Ramezani et al. (2014a), Asad et al. (2019), Chen et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Ghayebloo et al. (2015), Kaya and Urek (2016), Papen and Amin (2018), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018), Ramezani and Jafari (2018), Roghanian and Cheraghalipour (2019), Roghanian and Cheraghalipour (2019), Tokhmehchi et al. (2015), Wu et al. (2019)
Warehouses	Fleischmann et al. (2009), Beamon and Fernandes (2004), Salema et al. (2006), Ko and Evans (2007), Sharma et al. (2007), Du and Evans (2008), Min and Ko (2008), Mutha and Pokharel (2009), Salema et al. (2010), Das and Chowdhury (2012), Fahimnia et al. (2013), Soleimani et al. (2013a), Chen et al. (2014), Pazhani and A (2018), Pourjavad and Mayorga (2018), Ramezani and Jafari (2018)
Disposal centers	Lu and Bostel (2007), Sharma et al. (2007), Sheu (2008), Mutha and Pokharel (2009), Kannan et al. (2010), Pishvaee et al. (2010), Pishvaee et al. (2009b), Gomes et al. (2011), Krikke (2011), Dat et al. (2012), Kannan et al. (2012), Eskandarpour et al. (2013), Fahimnia et al. (2013), Soleimani et al. (2013a), Ramezani et al. (2014a), Chen et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Nallusamy et al. (2018), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018), Ramezani and Jafari (2018), Sherif et al. (2019), Tokhmehchi et al. (2015)
Disassembly centers (dismantlers)	Fleischmann et al. (2009), Salema et al. (2006), Schultmann et al. (2006), Demirel and Gökçen (2008), Lee et al. (2009), Kannan et al. (2010), Salema et al. (2010), Wang and Hsu (2010a), Paksoy et al. (2011), Dat et al. (2012), Özceylan and Paksoy (2013a), Soleimani et al. (2013a), Özceylan et al. (2014), Ghayebloo et al. (2015)
Capacity levels	Du and Evans (2008), Pishvaee et al. (2010), Eskandarpour et al. (2013), Keyvanshokooh et al. (2013)
Distributors (dealers)	Jayaraman et al. (1999), Üster et al. (2007), Demirel and Gökçen (2008), Lashkari and Zhang (2014), Pati et al. (2008), Zhou and Wang (2008), Kannan et al. (2008), Mutha and Pokharel (2009), Kannan et al. (2010), Pishvaee et al. (2010), Wang and Hsu (2010a), Paksoy et al. (2011), Özkır and Başlıgil (2012), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Devika et al. (2014), Diabat et al. (2015), Ramezani et al. (2014a)
Wholesalers	Sheu (2008), Kannan et al. (2008), Kannan et al. (2010), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018), Sherif et al. (2019)
Retailers	Üster et al. (2007), Kannan et al. (2008), Mutha and Pokharel (2009), Easwaran and Üster (2010), Kannan et al. (2010), Özceylan and Paksoy (2013a), Soleimani et al. (2013a), Özceylan et al. (2014), Diabat et al. (2015), Chen et al. (2014), Kaya and Urek (2016), Nallusamy et al. (2018), Papen and Amin (2018), Pazhani and A (2018), Sherif et al. (2019), Wu et al. (2019)
Recyclers	Lashkari and Duan (2007), Lashkari and Zhang (2014), Mutha and Pokharel (2009), Neto et al. (2009), Achillas et al. (2010), Sasikumar et al. (2010), Gomes et al. (2011), Amin and Zhang (2011), Dat et al. (2012), Fahimnia et al. (2013), Chen et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Pourjavad and Mayorga (2018), Roghanian and Cheraghalipour (2019), Sherif et al. (2019)
Repairers	Ko and Evans (2007), Min and Ko (2008), Dat et al. (2012), Ramezani et al. (2014a), Nallusamy et al. (2018), Nallusamy et al. (2018)
Collection facilities	Jayaraman et al. (1999), Beamon and Fernandes (2004), Min et al. (2006a), Min et al. (2006b), Üster et al. (2007), Demirel and Gökçen (2008), Du and Evans (2008), Cruz-Rivera and Ertel (2009), Kannan et al. (2008), Lee and Chan (2009), Neto et al. (2009), Achillas et al. (2010), Kannan et al. (2010), Pishvaee et al. (2010), Pishvaee et al. (2009b), Sasikumar et al. (2010), Paksoy et al. (2011), Alumur et al. (2012), Dat et al. (2012), Kannan et al. (2012), Özkır and Başlıgil (2012), Özceylan and Paksoy (2013a), Eskandarpour et al. (2013), Fahimnia et al. (2013), Devika et al. (2014), Özceylan et al. (2014), Ramezani et al. (2014a), Chen et al. (2014), Pourjavad and Mayorga (2018), Tokhmehchi et al. (2015)

Processing facilities	Ko and Evans (2007), Sheu et al. (2005), Ahluwalia and Nema (2006), Min et al. (2006a), Schultmann et al. (2006), Sheu (2008), Lee et al. (2009), Mutha and Pokharel (2009), Easwaran and Üster (2010), Sasikumar et al. (2010), Gomes et al. (2011), Assavapokee and Wongthatsanekorn (2012), Lundin (2012),
Recovery facilities	Tang et al. (2008), Zhou and Wang (2008), Zuidwijk and Krikke (2008), Lee et al. (2009), Neto et al. (2009), Pishvaee et al. (2010), Pishvaee et al. (2009b), Krikke (2011), Kannan et al. (2012), Özkır and Başlıgil (2012), Eskandarpour et al. (2013), Devika et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Pazhani and A (2018), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018)
Transportation modes	Lashkari and Zhang (2014), Achillas et al. (2010), Gomes et al. (2011), Assavapokee and Wongthatsanekorn (2012), Fahimnia et al. (2013), Sherif et al. (2019)
Refurbishing sites	Özceylan and Paksoy (2013a), Özceylan et al. (2014), Rezaee et al. (2016)
Quality levels Price levels	Jayaraman (2006), Krikke (2011), Das and Chowdhury (2012), Keyvanshokooh et al. (2013) Keyvanshokooh et al. (2013), Ramezani and Jafari (2018)
Capacity level	Pazhani and A (2018)

Table 3. Classification of deterministic optimization models based on constraints

Constraint	References
Demand	Jayaraman et al. (1999), Fleischmann et al. (2009), Ko and Evans (2007), Beamon and Fernandes (2004), Sheu et al. (2005), Salema et al. (2006), Jayaraman (2006), Kim et al. (2006), Min et al. (2006a), Min et al. (2006b), Lashkari and Duan (2007), Lu and Bostel (2007), Sharma et al. (2007), Sheu (2007), Üster et al. (2007), Demirel and Gökçen (2008), Du and Evans (2008), Lashkari and Zhang (2014), Min and Ko (2008), Pati et al. (2008), Sheu (2008), Tang et al. (2008), Zhou and Wang (2008), Zuidwijk and Krikke (2008), Cruz-Rivera and Ertel (2009), Gupta and Evans (2009), Kannan et al. (2008), Lee and Chan (2009), Lee et al. (2009), Neto et al. (2009), Pan et al. (2009), Xanthopoulos and Iakovou (2009), Achillas et al. (2010), Easwaran and Üster (2010), Kannan et al. (2010), Pishvaee et al. (2010), Pishvaee et al. (2009b), Salema et al. (2010), Sasikumar et al. (2010), Wang and Hsu (2010a), Gomes et al. (2011), Krikke (2011), Kumar and Chan (2011), Paksoy et al. (2011), Alumur et al. (2012), Amin and Zhang (2011), Assavapokee and Wongthatsanekorn (2012), Das and Chowdhury (2012), Dat et al. (2012), Kannan et al. (2012), Özkır and Başlıgil (2012), Lundin (2012), Zhang et al. (2012), Özceylan and Paksoy (2013a), Eskandarpour et al. (2013), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Devika et al. (2014), Özceylan et al. (2014), Diabat et al. (2015), Ramezani et al. (2014a), Chen et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Ghayebloo et al. (2015), Ghobadi and Esmaeili (2018), Kaya and Urek (2016), Nallusamy et al. (2018), Papen and Amin (2018), Pazhani and A (2018), Rezaee et al. (2016), Roghanian and Cheraghalipour (2019), Sherif et al. (2019), Tokhmehchi et al. (2015), Wu et al. (2019)
Capacity	Jayaraman et al. (1999), Fleischmann et al. (2009), Hu et al. (2002), Ko and Evans (2007), Beamon and Fernandes (2004), Sheu et al. (2005), Salema et al. (2006), Ahluwalia and Nema (2006), Jayaraman (2006), Kim et al. (2006), Min et al. (2006a), Min et al. (2006b), Schultmann et al. (2006), Lashkari and Duan (2007), Sheu (2007), Demirel and Gökçen (2008), Du and Evans (2008), Lashkari and Zhang (2014), Min and Ko (2008), Pati et al. (2008), Sheu (2008), Tang et al. (2008), Zhou and Wang (2008), Zuidwijk and Krikke (2008), Kannan et al. (2008), Lee and Chan (2009), Lee et al. (2009), Mutha and Pokharel (2009), Neto et al. (2009), Pan et al. (2009), Xanthopoulos and Iakovou (2009), Achillas et al. (2010), Easwaran and Üster (2010), Fröhling et al. (2010), Kannan et al. (2010), Pishvaee et al. (2010), Pishvaee et al. (2009b), Salema et al. (2010), Sasikumar et al. (2010), Wang and Hsu (2010a), Gomes et al. (2011), Krikke (2011), Kumar and Chan (2011), Paksoy et al. (2011), Alumur et al. (2012), Amin and Zhang (2011), Assavapokee and Wongthatsanekorn (2012), Das and Chowdhury (2012), Dat et al. (2012), Kannan et al. (2012), Özkır and Başlıgil (2012), Lundin (2012), Zhang et al. (2012), Özceylan and Paksoy (2013a), Eskandarpour et al. (2013), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Devika et al. (2014), Özceylan et al. (2014), Ramezani et al. (2014a), Chen et al. (2014), Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Ghayebloo et al. (2015), Kim and Jeong (2016), Nallusamy et al. (2018), Papen and Amin (2018), Pazhani and A (2018), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018), Ramezani and Jafari (2018), Rezaee et al. (2016), Roghanian and Cheraghalipour (2019), Sherif et al. (2019), Tokhmehchi et al. (2015), Wu et al. (2019)

Inventory	Hu et al. (2002), Sheu et al. (2005), Jayaraman (2006), Kim et al. (2006), Min and Ko (2008), Sheu (2008), Gupta and Evans (2009), Pan et al. (2009), Xanthopoulos and Iakovou (2009), Zhang et al. (2012), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Kaya and Urek (2016), Rad and Nahavandi (2018), Roghanian and Cheraghalipour (2019)
Min or max number of centers	Jayaraman et al. (1999), Min et al. (2006a), Pati et al. (2008), Lee et al. (2009), Xanthopoulos and Iakovou (2009), Sasikumar et al. (2010), Amin and Zhang (2011), Hasani et al. (2012), Özceylan and Paksoy (2013a), Soleimani et al. (2013a), Devika et al. (2014), Pourjavad and Mayorga (2018), Ramezani and Jafari (2018)
Budget	Pati et al. (2008), Ramezani et al. (2014a)
Processing time	Sheu (2007), Du and Evans (2008), Kannan et al. (2008), Kannan et al. (2010), Pishvaee et al. (2010)
Pricing	Keyvanshokooh et al. (2013), Ghobadi and Esmaeili (2018), Kaya and Urek (2016), Ramezani and Jafari (2018), Wu et al. (2019)
Min or max number of vehicles	Sherif et al. (2019)

Uncertain optimization models

For supply chain management, one of the main problems in model construction is uncertainty. More information about uncertain models in supply chain management are discussed in Peidro et al. (2008), Simangunsong et al. (2012), and Snyder (2006). We have classified the literature according to the multiple elements (like previous section) in Table 4. Uncertain optimization models have been categorized based on constraints in Table 5. We do not mention network constraints in the Table. Besides, the literature has been categorized to some groups according to the sources of uncertainty in Table 6. Fig. 2 shows the sources of uncertainty in CLSC.

Inderfurth (2005) used stochastic programming to develop a CLSC network that considered uncertainty in demand and return. Moreover, a parameter to measure uncertainty in quality was discussed. A fuzzy goal programming approach was taken by Selim and Ozkarahan (2006) for a reverse logistics network. The uncertainties in demand and opinions of decision makers for the goals were taken into consideration. Listeş (2007) proposed a two-stage stochastic integer programming model to configure a CLSC network. In the first stage, location decision has been made by minimizing total cost. Then, product flow has been determined by maximizing expected revenue in the second stage. The uncertainty in demand and return has been examined using alternative scenarios.

Salema et al. (2007) extended on the reverse logistics model developed Fleischmann et al. (2009) by taking scenario-dependent cases in considering uncertainty in demand and return. Vlachos et al. (2007) applied simulation and system dynamics to dynamic capacity planning of a CLSC. They also showed the application of the model by some numerical examples. Their approach is unique between other papers in this field. Li et al. (2008) proposed a multi-period optimization model for a waste management system. A fuzzy robust integer programming approach was used to take uncertainty into account. Francas and Minner (2009) proposed a two-stage stochastic model to configure a CLSC network. They investigated two networks. It has been supposed that demand and return are uncertain parameters. Unlike the most of CLSC papers, capacity is a decision variable. The authors examined two cases. In the first one, new as well as remanufactured products were carried to the same market. In the second one, remanufactured products were sent to the secondary market.

Ketzenberg (2009) investigated the value of information (demand, recovery yield, and capacity utilization) in a CLSC. In other words, they considered uncertainty in those parameters. In addition, they developed heuristics to solve the model. Lee and Dong (2009) constructed a mathematical model for a reverse logistics network using two-stages. An MILP model has been developed in the first stage. Then, to consider demand and return uncertainty, a stochastic model was used as an extension in the second stage. Although the model has been designed for multi-periods, inventory has been not taken into account. Pishvaee et al. (2009a) proposed a scenario-based stochastic optimization model for a reverse logistics network. Qin and Ji (2010) used three types of mathematicals model to construct a a reverse logistics network. Expected cost was minimized in the first and α-cost was minimised in the second. As for the third, credibility was maximized. In the study, costs and return were triangular fuzzy numbers. Shi et al. (2010) used lagrangian relaxation to develop an optimization model with a solution approach that considered uncertainty in demand and return.

Shi et al. (2011b) developed a stochastic model with uncertain demand and return for a CLSC. They took under-stocking as well as over-stocking costs into consideration to maximize the profit. Besides, they proposed an algorithm based on the properties of the model. Zhang et al. (2011) defined interval for parameters of a RL network to consider uncertainty. Then, they developed a piecewise interval programming approach to solve the model. Amin and Zhang (2012) developed an optimization model for a CLSC network. They considered supplier selection in their model by a fuzzy method and they calculated weight of each supplier. Then, they utilized the weights in a multi-objective mathematical model. Vahdani et al. (2012b) proposed a multi-objective model and solution approach based on fuzzy programming and robust optimization. They applied queuing theory in the model.

Amin and Zhang (2013a) proposed a three-stage model for selection of the best alternatives (suppliers, remanufacturing subcontractors, and refurbishing sites) and CLSC configuration. The demand has been considered as an uncertain parameter. Amin and Zhang (2013b) proposed a mixed-integer linear programming model for a CLSC. Then, they extended on the model to consider environmental objectives and uncertainty in two stages.

Alimoradi et al. (2014) designed a CLSC model while considering uncertain product returns in the reverse loop using fuzzy mixed integer linear programming that maximizes profit of the supply chain while minimizing the waste materials. Vahdani and Mohammadi (2015) introduced a new hybrid solution approach for optimizing the supply chain in regards to total costs and waiting times using fuzzy multi-objective programming, interval programming, robust optimization, and stochastic programming. While considering uncertainties of the demand rate and variable costs, Talaei et al. (2016) developed a bi-objective fuzzy mixed-integer linear programming model using the ε-constraint method that minimized the total supply chain costs and the rate of carbon dioxide emission. Fazli-Khalaf et al. (2017) tackled demand uncertainties by using a scenario-based fuzzy stochastic programming method in designing a CLSC network that minimizes the total costs and carbon emissions. Yavari and Geraeli (2019) took a different approach in designing the CLSC network by focusing on perishable goods in their model. The study developed a mixed-integer linear programming model using YAG method for optimization.

Table 4. Classification of uncertain optimization models based on multiple elements

Multiple elements	References
Parts	Inderfurth (2005), Rouf and Zhang (2011), Amin and Zhang (2012), Hasani et al. (2012), Özkır and Başlıgil (2013), Amin and Zhang (2013a), Wang and Huang (2013), Demirel et al. (2014), Jindal and Sangwan (2013), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Tosarkani et al. (2019)
Products	Inderfurth (2005), Salema et al. (2007), Selim and Ozkarahan (2006), Francas and Minner (2009), Lee and Dong (2009), Shi et al. (2010), Georgiadis et al. (2011), Rouf and Zhang (2011), Sasikumar and Haq (2011), Shi et al. (2011a), Amin and Zhang (2012), Amin and Zhang (2013a), Amin and Zhang (2013b), Hasani et al. (2012), Vahdani et al. (2012b) , Özkır and Başlıgil (2013), Ramezani et al. (2013), Vahdani et al. (2013a), Cardoso et al. (2013), Ramezani et al. (2012), Vahdani et al. (2013b), Wang and Huang (2013), Amin and Zhang (2014), Ramezani et al. (2014b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin et al. (2017), Amin and Baki (2017), Chen et al. (2018), Ghahremani-Nahr et al. (2019), Hajipour et al. (2019), Kai et al. (2016), Talaei et al. (2016), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Vahdani and Mohammadi (2015), Yavari and Geraeli (2019), Tosarkani et al. (2019)
Suppliers	El-Sayed et al. (2010), Wang and Hsu (2010b), Rouf and Zhang (2011), Amin and Zhang (2012), Amin and Zhang (2013a), Hasani et al. (2012), Vahdani et al. (2012b) , Ramezani et al. (2013), Ramezani et al. (2012), Demirel et al. (2014), Özceylan and Paksoy (2013b), Ramezani et al. (2014b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin et al. (2017), Amin and Baki (2017), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Hamdouch et al. (2016), Kim et al. (2018), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Yavari and Geraeli (2019), Tosarkani et al. (2019)

Periods	Inderfurth (2005), Li et al. (2008), Lee and Dong (2009), El-Sayed et al. (2010), Pishvaee and Torabi (2010) , Georgiadis et al. (2011), Zhang et al. (2011), Hasani et al. (2012), Vahdani et al. (2012a) , Özkır and Başlıgil (2013), Cardoso et al. (2013), Wang and Huang (2013), Demirel et al. (2014), Özceylan and Paksoy (2013b), Ramezani et al. (2014b), Zeballos et al. (2014), Ahmadi and Amin (2019), Chen et al. (2018), Ghahremani-Nahr et al. (2019), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Yavari and Geraeli (2019), Tosarkani et al. (2019)
Scenarios	Listeş (2007), Salema et al. (2007), Pishvaee et al. (2009a), Kara and Onut (2010), Amin and Zhang (2013b), Cardoso et al. (2013), Wang and Huang (2013), Soleimani et al. (2013b), Zeballos et al. (2014), Fazli-Khalaf et al. (2017), Tosarkani and Amin (2019), Vahdani and Mohammadi (2015), Tosarkani et al. (2019)
Plants (factories, manufacturers)	Listeş (2007), Salema et al. (2007), Selim and Ozkarahan (2006), Francas and Minner (2009), Lee and Dong (2009), Pishvaee and Torabi (2010) , Wang and Hsu (2010b), Georgiadis et al. (2011), Sasikumar and Haq (2011), Amin and Zhang (2013b), Hasani et al. (2012), Vahdani et al. (2012a) , Vahdani et al. (2012b) , Zeballos et al. (2012), Özkır and Başlıgil (2013), Ramezani et al. (2013), Vahdani et al. (2013a), Cardoso et al. (2013), Ramezani et al. (2012), Vahdani et al. (2013b), Amin and Zhang (2014), Demirel et al. (2014), Hatefi and Jolai (2014), Mirakhorli (2013), Ramezani et al. (2014b), Soleimani et al. (2013b), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin et al. (2017), Amin and Baki (2017), Fazli-Khalaf et al. (2017), Ghahremani-Nahr et al. (2019), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Hamdouch et al. (2016), Kai et al. (2016), Talaei et al. (2016), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Vahdani and Mohammadi (2015), Yavari and Geraeli (2019)
Markets (customers)	Lieckens and Vandaele (2007), Listeş (2007), Salema et al. (2007), Lee and Dong (2009), Pishvaee et al. (2009a), El-Sayed et al. (2010), Kara and Onut (2010), Pishvaee and Torabi (2010) , Qin and Ji (2010), Wang and Hsu (2010b), Georgiadis et al. (2011), Amin and Zhang (2013a), Pishvaee et al. (2011), Amin and Zhang (2013b), Vahdani et al. (2012a) , Vahdani et al. (2012b) , Zeballos et al. (2012), Özkır and Başlıgil (2013), Ramezani et al. (2013), Vahdani et al. (2013a), Cardoso et al. (2013), Ramezani et al. (2012), Vahdani et al. (2013b), Amin and Zhang (2014), Demirel et al. (2014), Hatefi and Jolai (2014), Mirakhorli (2013), Özceylan and Paksoy (2013b), Ramezani et al. (2014b), Soleimani et al. (2013b), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin et al. (2017), Fazli-Khalaf et al. (2017), Hajipour et al. (2019), Talaei et al. (2016), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Vahdani and Mohammadi (2015), Tosarkani et al. (2019)
Warehouses	Salema et al. (2007), Selim and Ozkarahan (2006), Georgiadis et al. (2011), Hasani et al. (2012), Zeballos et al. (2012), Cardoso et al. (2013), Soleimani et al. (2013b), Zeballos et al. (2014), Ghahremani-Nahr et al. (2019), Yavari and Geraeli (2019)
Wholesalers	Sasikumar and Haq (2011)
Disassembly centers	Salema et al. (2007), El-Sayed et al. (2010), Wang and Hsu (2010b), Sasikumar and Haq (2011), Zeballos et al. (2012), Demirel et al. (2014), Özceylan and Paksoy (2013b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Zeballos et al. (2014)
Capacity levels	Lieckens and Vandaele (2007), Selim and Ozkarahan (2006), Ramezani et al. (2013), Ramezani et al. (2012), Fazli-Khalaf et al. (2017)
Distributors	Pishvaee et al. (2009a), El-Sayed et al. (2010), Pishvaee and Torabi (2010) , Wang and Hsu (2010b), Pishvaee et al. (2011), Zhang et al. (2011), Abdallah et al. (2011), Vahdani et al. (2012b) , Özkır and Başlıgil (2013), Vahdani et al. (2013a), Ramezani et al. (2012), Demirel et al. (2014), Hatefi and Jolai (2014), Mirakhorli (2013), Soleimani et al. (2013b), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin and Baki (2017), Ghahremani-Nahr et al. (2019), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Kai et al. (2016)
Disposal centers	Pishvaee et al. (2009a), El-Sayed et al. (2010), Pishvaee et al. (2011), Zhang et al. (2011), Zeballos et al. (2012), Ramezani et al. (2013), Cardoso et al. (2013), Ramezani et al. (2012), Hatefi and Jolai (2014), Ramezani et al. (2014b), Soleimani et al. (2013b), Zeballos et al. (2014), Amin and Baki (2017), Fazli-Khalaf et al. (2017), Ghahremani-Nahr et al. (2019), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Kai et al. (2016), Vahdani and Mohammadi (2015)
Collection	Lee and Dong (2009), Pishvaee and Torabi (2010) , Qin and Ji (2010), Pishvaee et al. (2011), Sasikumar and Haq

facilities	(2011), Zhang et al. (2011), Amin and Zhang (2013b), Vahdani et al. (2012a) , Vahdani et al. (2012b) , Özkır and Başlıgil (2013), Ramezani et al. (2013), Vahdani et al. (2013a), Ramezani et al. (2012), Amin and Zhang (2014), Demirel et al. (2014), Hatefi and Jolai (2014), Mirakhorli (2013), Özceylan and Paksoy (2013b), Jindal and Sangwan (2013), Zeballos et al. (2014), Alimoradi et al. (2014), Amin and Baki (2017), Fazli-Khalaf et al. (2017), Hajipour et al. (2019), Kai et al. (2016), Talaei et al. (2016), Tosarkani and Amin (2018b), Yavari and Geraeli (2019), Tosarkani et al. (2019)
Processing facilities	Lieckens and Vandaele (2007), Li et al. (2008), Lee and Dong (2009), El-Sayed et al. (2010), Vahdani et al. (2012b) , Vahdani et al. (2013a), Cardoso et al. (2013), Vahdani et al. (2013b), Ramezani et al. (2014b)
Recovery facilities	Listeş (2007), Pishvaee et al. (2009a), Pishvaee and Torabi (2010) , Vahdani et al. (2012a) , Özkır and Başlıgil (2013), Amin and Zhang (2014), Hatefi and Jolai (2014), Hamdouch et al. (2016), Tosarkani and Amin (2018a), Tosarkani and Amin (2019), Tosarkani et al. (2019)
Recyclers	Kara and Onut (2010), Pishvaee and Torabi (2010), Fazli-Khalaf et al. (2017), Ghahremani-Nahr et al. (2019), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Kim et al. (2018)
Retailers	Selim and Ozkarahan (2006), Sasikumar and Haq (2011), Abdallah et al. (2011), Hasani et al. (2012), Özceylan and Paksoy (2013b), Soleimani et al. (2013b), Ahmadi and Amin (2019), Amin et al. (2017), Hamdouch et al. (2016), Kai et al. (2016), Tosarkani and Amin (2018a), Yavari and Geraeli (2019), Tosarkani et al. (2019)
Refurbishing sites	Amin and Zhang (2012), Amin and Zhang (2013a), Demirel et al. (2014), Özceylan and Paksoy (2013b), Jindal and Sangwan (2013)
Subcontractors	Amin and Zhang (2013a)
Remanufacturing centers	Abdallah et al. (2011), Alimoradi et al. (2014), Kim et al. (2018), Tosarkani and Amin (2018b), Tosarkani et al. (2019)
Quality levels	Wang and Huang (2013)

Table 5. Classification of uncertain optimization models based on constraints

Constraint	References
Demand	Inderfurth (2005), Lieckens and Vandaele (2007), Listeş (2007), Salema et al. (2007), Li et al. (2008), Selim and Ozkarahan (2006), Francas and Minner (2009), Lee and Dong (2009), Pishvaee et al. (2009a), El-Sayed et al. (2010), Kara and Onut (2010), Pishvaee and Torabi (2010) , Wang and Hsu (2010b), Georgiadis et al. (2011), Pishvaee et al. (2011), Sasikumar and Haq (2011), Shi et al. (2011b), Zhang et al. (2011), Amin and Zhang (2012), Amin and Zhang (2013b), Hasani et al. (2012), Vahdani et al. (2012a) , Özkır and Başlıgil (2013), Vahdani et al. (2012b) , Zeballos et al. (2012), Ramezani et al. (2013), Vahdani et al. (2013a), Cardoso et al. (2013), Ramezani et al. (2012), Vahdani et al. (2013b), Wang and Huang (2013), Amin and Zhang (2014), Demirel et al. (2014), Hatefi and Jolai (2014), Mirakhorli (2013), Ramezani et al. (2014b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin et al. (2017), Amin and Baki (2017), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Hamdouch et al. (2016), Kai et al. (2016), Kim et al. (2018), Talaei et al. (2016), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Yavari and Geraeli (2019)
Capacity	Lieckens and Vandaele (2007), Listeş (2007), Salema et al. (2007), Li et al. (2008), Selim and Ozkarahan (2006), Francas and Minner (2009), Lee and Dong (2009), Pishvaee et al. (2009a), El-Sayed et al. (2010), Kara and Onut (2010), Pishvaee and Torabi (2010) , Qin and Ji (2010), Shi et al. (2010), Wang and Hsu (2010b), Georgiadis et al. (2011), Rouf and Zhang (2011), Shi et al. (2011a), Shi et al. (2011b), Amin and Zhang (2012), Amin and Zhang (2013a), Amin and Zhang (2013b), Pishvaee et al. (2011), Sasikumar and Haq (2011), Hasani et al. (2012), Vahdani et al. (2012a) , Vahdani et al. (2012b) , Zeballos et al. (2012), Özkır and Başlıgil (2013), Ramezani et al. (2013), Vahdani et al. (2013a), Cardoso et al. (2013), Ramezani et al. (2012), Vahdani et al. (2013b), Wang and Huang (2013), Amin and Zhang (2014), Demirel et al. (2014), Hatefi and Jolai (2014), Mirakhorli (2013), Ramezani et al. (2014b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin et al. (2017), Amin and Baki (2017), Fazli-Khalaf et al. (2017), Ghahremani-Nahr et al. (2019), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Kai et al. (2016), Kim et al. (2018), Talaei et al. (2016), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani and Amin (2019), Vahdani and Mohammadi

	(2015), Yavari and Geraeli (2019), Tosarkani et al. (2019)
Inventory	Inderfurth (2005), Lieckens and Vandaele (2007), El-Sayed et al. (2010), Zhang et al. (2011), Mitra (2012), Ghahremani-Nahr et al. (2019)
Min or max number of centers	Lee and Dong (2009), El-Sayed et al. (2010), Qin and Ji (2010), Shi et al. (2011b), Amin and Zhang (2013a), Ramezani et al. (2012), Soleimani et al. (2013b), Hajipour et al. (2019)
Budget	Qin and Ji (2010)
Processing time	El-Sayed et al. (2010), Pishvaee and Torabi (2010)

Table 6. Classification of references based on sources of uncertainty

Source of uncertainty	References
Demand	Inderfurth (2005), Lieckens and Vandaele (2007), Listeş (2007), Salema et al. (2007), Selim and Ozkarahan (2006), Francas and Minner (2009), Ketzenberg (2009), Lee and Dong (2009), Pishvaee et al. (2009a), El-Sayed et al. (2010), Kara and Onut (2010), Pishvaee and Torabi (2010) , Shi et al. (2010), Wang and Hsu (2010b), Georgiadis et al. (2011), Pishvaee et al. (2011), Rouf and Zhang (2011), Shi et al. (2011a), Shi et al. (2011b), Abdallah et al. (2011), Mitra (2012), Amin and Zhang (2013a), Amin and Zhang (2013b), Hasani et al. (2012), Vahdani et al. (2012a) , Özkır and Başlıgil (2013), Ramezani et al. (2013), Vahdani et al. (2013a), Cardoso et al. (2013), Ramezani et al. (2012), Vahdani et al. (2013b), Wang and Huang (2013), Amin and Zhang (2014), Hatefi and Jolai (2014), Mirakhorli (2013), Özceylan and Paksoy (2013b), Ramezani et al. (2014b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Ahmadi and Amin (2019), Amin et al. (2017), Amin and Baki (2017), Chen et al. (2018), Ghahremani-Nahr et al. (2019), Ghomi-Avili et al. (2018), Hajipour et al. (2019), Hamdouch et al. (2016), Kim et al. (2018), Talaei et al. (2016), Tosarkani and Amin (2018a), Yavari and Geraeli (2019)
Capacity	Li et al. (2008), Ketzenberg (2009), Pishvaee and Torabi (2010) , Vahdani et al. (2012b) , Vahdani et al. (2013a), Vahdani et al. (2013b), Özceylan and Paksoy (2013b), Ramezani et al. (2014b), Zeballos et al. (2014), Fazli-Khalaf et al. (2017), Tosarkani and Amin (2019), Vahdani and Mohammadi (2015)
Delivery time	Pishvaee and Torabi (2010) , Abdallah et al. (2011), Tosarkani and Amin (2018b)
Processing time	Kai et al. (2016)
Quality	Inderfurth (2005), Zeballos et al. (2012), Hatefi and Jolai (2014)
Return	Inderfurth (2005), Lieckens and Vandaele (2007), Listeş (2007), Salema et al. (2007), Li et al. (2008), Francas and Minner (2009), Ketzenberg (2009), Lee and Dong (2009), Pishvaee et al. (2009a), Pishvaee and Torabi (2010) , Qin and Ji (2010), Shi et al. (2010), Wang and Hsu (2010b), Pishvaee et al. (2011), Rouf and Zhang (2011), Shi et al. (2011a), Shi et al. (2011b), Abdallah et al. (2011), Mitra (2012), Amin and Zhang (2013b), Vahdani et al. (2012b) , Zeballos et al. (2012), Özkır and Başlıgil (2013), Vahdani et al. (2013a), Ramezani et al. (2012), Vahdani et al. (2013b), Amin and Zhang (2014), Hatefi and Jolai (2014), Özceylan and Paksoy (2013b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Zeballos et al. (2014), Ahmadi and Amin (2019), Alimoradi et al. (2014), Amin et al. (2017), Ghahremani-Nahr et al. (2019), Hamdouch et al. (2016), Kai et al. (2016)
Cost	Li et al. (2008), Pishvaee et al. (2009a), Pishvaee and Torabi (2010) , Qin and Ji (2010), Pishvaee et al. (2011), Hasani et al. (2012), Vahdani et al. (2012a) , Özkır and Başlıgil (2013), Vahdani et al. (2012b) , Vahdani et al. (2013a), Vahdani et al. (2013b), Demirel et al. (2014), Ramezani et al. (2014b), Soleimani et al. (2013b), Jindal and Sangwan (2013), Ghahremani-Nahr et al. (2019), Kai et al. (2016), Talaei et al. (2016), Tosarkani and Amin (2019), Vahdani and Mohammadi (2015), Tosarkani et al. (2019)
Decision-making	Selim and Ozkarahan (2006), Sasikumar and Haq (2011), Zhang et al. (2011), Amin and Zhang (2012), Amin and Zhang (2013a)

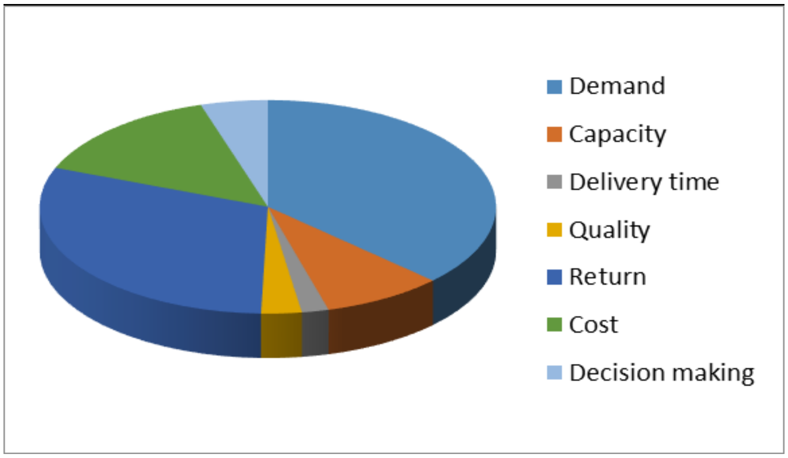

Figure 2. Sources of uncertainty

Game-theoretic models

In this section, some game-theoretic models related to CLSC networks are reviewed. As we mentioned before, in game-theoretic models some decision-makers (players) can contribute in decision-making process. It is noticeable that we focus on papers related to the application of game theory in CLSC (not reverse logistics). Generally, demand functions are defined in these articles. Then, payoff functions (e.g. profit) are developed. The goal is to find equilibrium. In equilibrium, outcome of each player cannot be improved, given the others' strategy. For more information about game theory in supply chain management, interested readers can refer to Leng and Parlar (2005).

Savaskan et al. (2004) considered three options for the manufacturer to collect used-products: by directly collecting from customers, having a retailer collecting the products, or the use of a third party to collect the used-products. The authors calculated Stackelberg equilibrium.

Debo et al. (2005) discussed production technology selection in a remanufacturing system. They supposed that manufacturer chooses level of remanufacturing by technology selection and she wants to maximize her profit. Heese et al. (2005) investigated the effects of returning used-products on the profit and sales. They considered competition between two manufacturers to sell a product. Four cases have been examined: both manufacturers return used-products, one of them return them, no one returns them. By calculating Nash and Stackelberg equilibriums, they found that returning can raise both profit margins and sales.

Hammond and Beullens (2007) considered a CLSC network for electric and electronic equipments and they found equilibrium by variational inequalities. The CLSC network includes manufacturers and customer markets.

Webster and Mitra (2007) proposed a two-period model for take-back products where two options were considered. First, the manufacturer does not have control on the returning process. Second, the manufacturer has complete control.

Atasu et al. (2008) proposed models for a remanufacturing system. They examined the effects of three factors on the system: competition between original equipment manufacturers, the existence of a green segment, and impacts of product life-cycle.

Mitra and Webster (2008) developed a two-period model using Nash Equilibrium. In the first period, only the manufacturer sells the products. While in the second period, a remanufacturer competes with the manufacturer. Moreover, the impact of government subsidies was analyzed.

Majumder and Groenevelt (2009) developed a two-period model for a remanufacturing system including an original equipment manufacturer and another local remanufacturer. For the second period, the Nash equilibrium of the system was calculated.

Yang et al. (2009) extended on the model developed by Hammond and Beullens (2007) and utilized variational inequalities to find equilibrium of a CLSC network. The network consists of suppliers, manufacturers, retailers, customers, and recovery centers.

Chen and Bell (2011) proposed a supply chain mathematical model that included a manufacturer and a retailer with stochastic demand. They proposed an agreement for them consists of two buyback prices.

Chen (2011) investigated the effect of information about customer returns on a supply chain network based on buyback policy. A single-period newsvendor problem was solved with Stackelberg game.

Chen and Chang (2012) examined a remanufacturing system under two scenarios: decentralized and centralized settings. The system includes an original equipment manufacturer (OEM) and independent operators.

Hong and Yeh (2012) developed and compared recycling models with retailer and non-retailer used product collection. For the first model, the retailer collected end-of-life products and then they were handled by a third-party company. In the second model, collection activities were subcontracted to a third-party firm by the manufacturer.

Choi et al. (2013) considered a CLSC including a retailer, a collector, and a manufacturer. They considered different leaders (scenarios) in the network and concluded that retailer as leader can lead to the most effective CLSC.

Guo and Ma (2013) proposed a price game model for a CLSC network including a manufacturer and a retailer. They calculated Stackelberg equilibrium.

Huang et al. (2013) conducted a research about CLSC which has dual recycling channels. A manufacturer sells products by a retailer in forward supply chain. However, in the reverse supply chain the retailer competes with a third-party company in collecting the returned products. Results for both centralized and decentralized channels were provided.

Qiang et al. (2013) examined a CLSC network with suppliers, retailers, and manufacturers as decentralized decision-makers. Variational inequality has been utilized to calculate equilibriums. The authors considered uncertainties in yield and demand.

Wei and Zhao (2013) considered a CLSC network. The manufacturer can produce new products or remanufacture used products. There are three options for collecting the products. They can be collected by the manufacturer, third party, or retailer. The authors compared the options.

Zhou et al. (2013) investigated an original equipment manufacturer and a supplier. The manufacturer can purchase new parts from supplier and also it can remanufacture returned products. They considered both centralized and decentralized control modes. They provided a conceptual framework as result.

Chen (2014) investigated a remanufacturing model in both cooperative and competitive policies. The objective functions are profit maximization. The network includes third-party independent operator and original equipment manufacturer.

A two-period CLSC network was considered by Giovanni and Zaccour (2014) where processing of used products is decided by the manufacturer, while collection of the used products is done by the manufacturer, retailer, or a third-party.

Feng et al. (2014) calculated equilibrium solutions of a CLSC network including suppliers, manufacturers, retailers, and customers. They applied variational inequalities.

Ma and Wang (2014) investigated a CLSC which includes one manufacturer and one retailer by two games (Stackelberg and peer-t-peer games). It is supposed that retailer collects used products.

Esmaeili et al. (2015) examined different pricing models by using Stackelberg game to consider the manufacturer-retailer interaction to identify the optimal pricing strategy for each model.

Wei et al. (2015) considered a CLSC including a manufacturer and a retailer. Remanufacturing of the used products is also done by the manufacturer. The authors solved four games with symmetric and asymmetric information structures. Then, they analysed the results.

Aydin et al. (2016) coordinated manufacturers with other supply chain players by developing a Stackelberg game theory model that considered both manufacturing and remanufacturing from a product line design perspective.

Huang and Wang (2017) used Stackelberg game to develop product recovery CLSC models which considered different remanufacturing strategies between the manufacturer, distributor, and the use of a third party under technology licensing.

Ghobadi and Esmaeili (2018) developed static and dynamic game theory models for pricing and supplier selection in a CLSC. The models used found the Stackelberg and Nash equilibriums of the manufacturer-supplier interactions. Moreover, a sensitivity analysis for the factors of these interactions was presented.

Patne et al. (2018) incorporated game theory and particle swarm optimization to create a framework that addressed certain challenges in CLSCs.

De Giovanni and Zaccour (2019) studied game theory models with regards to both product return rate functions and players coordination mechanisms.

Wang et al. (2019) took an environmental approach by using the Stackelberg game to consider product recovery and donation options. Different scenarios discussing which option is more favorable were provided.

Yang and Xu (2019) introduced a differential game CLSC model to analyze different behaviors of the players in the network under dynamic circumstances while considering carbon emission permits.

Zhao and Sun (2019) used game theory to compare profits distribution patterns of CLSCs before and after considering government subsidies.

Operations research techniques

In this section, we do not analyse game-theoretic models. Deterministic and uncertain optimization models have been divided to two main categories: single technique and hybrid techniques. In hybrid category, two or more techniques have been combined together. Table 7 shows the references based on operations research techniques.

Some authors have utilized integer linear programming models to calculate the numbers of products in the CLSC networks. They believe that variables must be integer because they represent numbers of products. On the other hand, some authors have utilized linear programming models with nonnegative variables to avoid computational complexity. In addition, some authors have developed stochastic programming models with stochastic objective functions: maximization of expected profit or minimization of expected cost. In those papers, a few parameters such as demand follow probability distributions (e.g. normal distribution).

The literature has been categorized according to the type of objective functions (mono-objective and multi-objective) in Table 8. Fig. 3 illustrates mono-objective versus multi-objective functions.

Table 7. Classification of references based on operations research techniques

	Techniques	References
Single technique	Linear programming (LP)	Hu et al. (2002), Sheu et al. (2005), Jayaraman (2006), Sheu (2007), Sheu (2008), Gupta and Evans (2009), Paksoy et al. (2011)
	Integer LP	Lashkari and Duan (2007), Zuidwijk and Krikke (2008), Mutha and Pokharel (2009), Lundin (2012)
	Mixed-integer linear programming (MILP)	Jayaraman et al. (1999), Fleischmann et al. (2009), Beamon and Fernandes (2004), Salema et al. (2006), Ahluwalia and Nema (2006), Kim et al. (2006), Schultmann et al. (2006), Sharma et al. (2007), Demirel and Gökçen (2008), Lashkari and Zhang (2014), Pati et al. (2008), Zhou and Wang (2008), Cruz-Rivera and Ertel (2009), Achillas et al. (2010), Georgiadis et al. (2011), Krikke (2011), Alumur et al. (2012), Amin and Zhang (2011), Assavapokee and Wongthatsanekorn (2012), Das and Chowdhury (2012), Dat et al. (2012), Kannan et al. (2012), Özkır and Başlıgil (2012), Özceylan and Paksoy (2013a), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Ramezani et al. (2014a), Ahmadi and Amin (2019), Ghayebloo et al. (2015), Kim and Jeong (2016), Nallusamy et al. (2018), Papen and Amin (2018), Pourjavad and Mayorga (2018), Rad and Nahavandi (2018), Sherif et al. (2019)
	Mixed-integer nonlinear programming (MINLP)	Sasikumar et al. (2010), Abdallah et al. (2011), Amin and Zhang (2013a), Amin and Zhang (2013b), Asad et al. (2019)
	Stochastic programming (SP)	Inderfurth (2005), Francas and Minner (2009), El-Sayed et al. (2010), Kara and Onut (2010), Rouf and Zhang (2011), Mitra (2012), Fathollahi-Fard and Hajiaghaei-Keshteli (2018)
	Piecewise interval LP	Zhang et al. (2011)
	Nash equilibrium	Wu et al. (2019)
	Stackleberg game	Huang and Wang (2017)
	Extra-gradient method	Hamdouch et al. (2016)
Hybrid techniques	Dynamic programming, heuristics	Ketzenberg (2009)
	Fuzzy goal programming	Selim and Ozkarahan (2006)
	Fuzzy programming, fuzzy simulation, genetic algorithm (GA)	Qin and Ji (2010), Alimoradi et al. (2014)
	Fuzzy QFD, MILP, SP	Amin and Zhang (2013a)
	Fuzzy programming, interval programming	Wang and Hsu (2010b)
	Fully Fuzzy Programming (FFP), Fuzzy Analytic Network Process (FANP)	Tosarkani and Amin (2018a)

	Integer LP, GA, particle swarm optimization	Kannan et al. (2008)
	Integer LP, spanning tree, GA	Wang and Hsu (2010a)
	Interval programming, SP, Robust Optimization (RO), fuzzy programming	Vahdani and Mohammadi (2015)
	LP, simulation	Fröhling et al. (2010)
	LP, heuristic	Neto et al. (2009)
	LP, dynamic programming	Pan et al. (2009)
	MILP, benders decomposition	Üster et al. (2007), Easwaran and Üster (2010)
	MILP, GA, Firefly Algorithm (FA)	Tokhmehchi et al. (2015)
	MILP, Mathematical Programming	Ramezani and Jafari (2018)
	MILP, Bertrand model	Ghobadi and Esmaeili (2018)
	MILP, Piecewise linearization	Kaya and Urek (2016)
	MILP, SP	Salema et al. (2007), Pishvaee et al. (2009a), Zeballos et al. (2012), Ramezani et al. (2013), Amin and Zhang (2013b), Cardoso et al. (2013), Amin and Zhang (2014), Soleimani et al. (2013b), Zeballos et al. (2014)
	MILP, YAG method	Yavari and Geraeli (2019)
	Full Fuzzy Stochastic Programming (FFSP)	Tosarkani and Amin (2019)
	MILP, FANP	Tosarkani and Amin (2018b)
	MILP, decision tree	Amin et al. (2017)
	MILP, Paired Comparison Method (PCM)	Pazhani and A (2018)
	MILP, fuzzy VIKOR	Sasikumar and Haq (2011)
	MILP, variable neighborhood search	Eskandarpour et al. (2013)
	MILP, hybrid heuristics	Devika et al. (2014)
	MILP, GA	Min and Ko (2008), Lee et al. (2009), Kannan et al. (2010), Soleimani et al. (2013a) Chen et al. (2014)

	MILP, Multi-Objective Tree Growth Algorithm (MOTGA)	Roghanian and Cheraghalipour (2019)
	MILP, Robust Heuristics	Kim et al. (2018)
	MILP, fuzzy programming	Chen et al. (2018), Tosarkani et al. (2019)
	MILP, Data Envelopment Analysis (DEA)	Rezaee et al. (2016)
	MILP, GA, fuzzy programming	Demirel et al. (2014), Mirakhorli (2013)
	MILP, Fuzzy programming, PSO	Kai et al. (2016)
	MILP, graph approach	Salema et al. (2010), Gomes et al. (2011)
	MILP, lagrangian heuristics	Lu and Bostel (2007), Zhang et al. (2012)
	MILP, multi-criteria decision-making	Xanthopoulos and Iakovou (2009)
	MILP, robust optimization (RO)	Pishvaee et al. (2011), Wang and Huang (2013), Hatefi and Jolai (2014)
	MILP, RO, fuzzy programming	Li et al. (2008), Fazli-Khalaf et al. (2017)
	MILP, scatter search	Du and Evans (2008)
	MILP, simulated annealing (SA)	Tang et al. (2008), Pishvaee et al. (2009b)
	MILP, RO, scenario relaxation algorithm	Ramezani et al. (2012)
	MILP, SP, SA	Lee and Dong (2009)
	MILP, MINLP, differential evolution	Lieckens and Vandaele (2007)
	MILP, superiority search and algorithm	Kumar and Chan (2011)
	MINLP, GA	Min et al. (2006a), Min et al. (2006b), Ko and Evans (2007)
	MILP, fuzzy sets theory and programming	Amin and Zhang (2012), Özkır and Başlıgil (2013), Ramezani et al. (2014b), Jindal and Sangwan (2013), Chen et al. (2018)
	MILP, Robust Fuzzy Programming (RFP)	Talaei et al. (2016)
	MILP, memetic algorithm	Pishvaee et al. (2010)
	MILP, fuzzy programming, possibilistic programming	Pishvaee and Torabi (2010), Vahdani et al. (2012b), Vahdani et al. (2013a), Vahdani et al. (2013b), Amin and Baki (2017), Ghomi-Avili et al. (2018)
	MINLP, fuzzy programming, possibilistic	Vahdani et al. (2012a)

	programming	
	MINLP, fuzzy programming	Özceylan and Paksoy (2013b)
	MINLP, Greedy Randomized adaptive Search Procedure (GRASP), PSO	
	MINLP, Robust Fuzzy Programming (RFP), Whale Optimization Algorithm (WOA)	Ghahremani-Nahr et al. (2019)
	Nonlinear programming (NLP), GA	Lee and Chan (2009)
	NLP, lagrangian relaxation	Shi et al. (2010), Shi et al. (2011b), Diabat et al. (2015)
	NLP, solution procedure	Shi et al. (2011a)
	NLP, RO	Hasani et al. (2012)
	SP, decomposition approach	Listes (2007)
	Simulation, systems dynamics	Vlachos et al. (2007)

Table 8. **Types of objective functions**

	Objective functions	References
Mono- objective	Max net present value	Cardoso et al. (2013)
	Max change in equity	Ramezani et al. (2014a)
	Max cost saving	Kim et al. (2006)
	Max contribution margin	Fröhling et al. (2010)
	Max coverage of customers	Lee and Chan (2009)
	Max profit	Lieckens and Vandaele (2007), Sharma et al. (2007), Chung et al. (2008), Tang et al. (2008), Zuidwijk and Krikke (2008), Francas and Minner (2009), Xanthopoulos and Iakovou (2009), El-Sayed et al. (2010), Kara and Onut (2010), Sasikumar et al. (2010), Shi et al. (2010), Yuan and Gao (2009), Rouf and Zhang (2011), Shi et al. (2011a), Shi et al. (2011b), Alumur et al. (2012), Amin and Zhang (2011), Assavapokee and Wongthatsanekorn (2012), Das and Chowdhury (2012), Özkır and Başlıgil (2012), Zeballos et al. (2012), Ramezani et al. (2012), Wang and Huang (2013), Demirel et al. (2014), Soleimani et al. (2013b), Jindal and Sangwan (2013), Amin et al. (2017), Chen et al. (2014), Esmaeili et al. (2015), Ghobadi and Esmaeili (2018), Hajipour et al. (2019), Hamdouch et al. (2016), Huang and Wang (2017), Kaya and Urek (2016), Nallusamy et al. (2018)
	Min cost	Jayaraman et al. (1999), Fleischmann et al. (2009), Hu et al. (2002), Beamon and Fernandes (2004), Inderfurth (2005), Salema et al. (2006), Jayaraman (2006), Min et al. (2006a), Min et al. (2006b), Schultmann et al. (2006), Ko and Evans (2007), Lashkari and Duan (2007), Lu and Bostel (2007), Salema et al. (2007), Üster et al. (2007), Demirel and Gökçen (2008), Li et al. (2008), Min and Ko (2008), Zhou and Wang (2008), Cruz-Rivera and Ertel (2009), Kannan et al. (2008), Ketzenberg (2009), Lee and Dong (2009), Lee et al. (2009), Mutha and Pokharel (2009), Pan et al. (2009), Pishvaee et al. (2009a), Achillas et al. (2010), Easwaran and Üster (2010), Kannan et al. (2010), Pishvaee et al. (2009b), Salema et al. (2010), Wang and Hsu (2010a), Wang and Hsu (2010b), Georgiadis et al. (2011), Gomes et al. (2011), Krikke (2011), Kumar and Chan (2011), Paksoy et al. (2011), Pishvaee et al. (2011), Sasikumar and Haq (2011), Zhang et al. (2011), Abdallah et al. (2011), Dat et al. (2012), Mitra (2012), Kannan et al. (2012), Hasani et al. (2012), Lundin (2012), Vahdani et al. (2012a) , Zhang et al. (2012), Özceylan and Paksoy (2013a), Fahimnia et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013a), Özceylan et al. (2014), Diabat et al. (2015), Hatefi and Jolai (2014), Zeballos et al. (2014), Alimoradi et al. (2014), Asad et al. (2019), Chen et al. (2018), Ghahremani-Nahr et al. (2019), Pourjavad and Mayorga (2018), Tokhmehchi et al. (2015)
Multi-objective	(2) Max supply chain-based net profit, min reverse chain-based net cost	Sheu (2008)
	(3) Max profit, and importance of suppliers, min defect rates	Amin and Zhang (2012)
	(2) Max manufacturing chain-based net profit, and reverse chain-based net profit	Sheu et al. (2005)
	(2) Min costs in first stage, max profits in second stage	Listeş (2007)
	(3) Min expected cost, and α-cost, max credibility	Qin and Ji (2010)
	(2) Min cost, max environmental objectives	Amin and Zhang (2013b), Fazli-Khalaf et al. (2017)
	(2) Min cost, and	Ahluwalia and Nema (2006)

	environmental risk	
	(2) Min cost, and pollution emissions	Lashkari and Zhang (2014), Kai et al. (2016)
	(2) Min costs, and risks	Sheu (2007)
	(2) Min costs, and expected transportation costs	Vahdani et al. (2013b)
	(4) Min cost, and defect rates, max weights, and on-time delivery	Amin and Zhang (2013a)
	(2) Max forward, and reverse profits (goal programming)	Gupta and Evans (2009)
	(3) Min cost, max product quality improvement, and environmental benefits (goal programming)	Pati et al. (2008)
	(2) Min costs, and total tardiness of cycle time	Du and Evans (2008)
	(3) Min costs, total tardiness, and environmental pollution	Eskandarpour et al. (2013)
	(3) Min costs, energy demand, and waste	Neto et al. (2009)
	(3) Min costs, and environmental impacts, max social benefits	Devika et al. (2014)
	(2) Min costs, and expected costs	Vahdani et al. (2012b) , Vahdani et al. (2013a)
	(3) Min cost, and investment, max service level (goal programming)	Selim and Ozkarahan (2006)
	(2) Min cost, max responsiveness	Pishvaee et al. (2010)
	(2) Min cost, and delivery tardiness	Pishvaee and Torabi (2010) , Mirakhorli (2013)
	(3) Max profits, satisfaction level of trade, and satisfaction degrees of customers	Özkır and Başlıgil (2013)
	(3) Max profit, responsiveness, and quality	Ramezani et al. (2013)
	(3) Min cost, defect rate, and time of operations	Amin and Zhang (2014)
	Min cost and CO2 emissions, Max demand responsiveness	Roghanian and Cheraghalipour (2019)
	(4) Min transportation, purchasing, refurbishing, and fixed costs	Özceylan and Paksoy (2013b)
	(3) Max profit, and quality, min delivery time Max profit and weights of eligible suppliers	Ramezani et al. (2014b) Ahmadi and Amin (2019)
	Max profit and efficiency, min defective rate of parts and functions of delivery delay	Rezaee et al. (2016)

	Max profit and on-time delivery	Amin and Baki (2017)
	Max profit, min energy usage	Pazhani and A (2018)
	Min cost, and environmental impact	Fathollahi-Fard and Hajiaghaei-Keshteli (2018), Kim and Jeong (2016), Talaei et al. (2016), Yavari and Geraeli (2019)
	Min cost and maximum waiting times	Vahdani and Mohammadi (2015)
	Max profit, and greenness	Ghayebloo et al. (2015)
	Max profit, min environmental impact	Ghomi-Avili et al. (2018), Papen and Amin (2018), Yang and Xu (2019)
	Min cost, max the valye of purchases from suppliers with higher evaluation scores	Ramezani and Jafari (2018)
	Min economic cost a nd CO2 emissions, max customer satisfaction	Rad and Nahavandi (2018)
	Min sum of distribution centers and green house emissions	Sherif et al. (2019)
	Max profit and green performance	Tosarkani and Amin (2018a), Tosarkani and Amin (2019), Wu et al. (2019)
	Max profit, green performance and on time-delivery, min defect rate.	Tosarkani and Amin (2018b)
	Max profit and environmental compliance	Tosarkani et al. (2019)

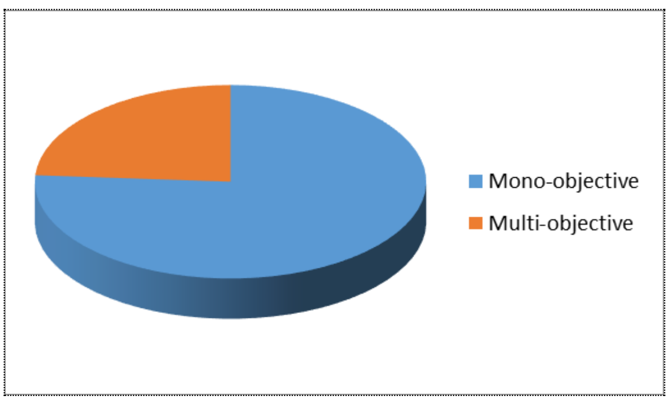

Figure 3 Mono-objective versus multi-objective functions

Observations and recommendations

In this section, we discuss some observations and recommendations based on the articles that have been reviewed within four domains.

The most popular domain

Out of the four CLSC domains discussed in this paper (literature reviews, deterministic optimization models, uncertain optimization models, and game-theoretic models), the most popular domain is the deterministic optimization models. For this domain, it was observed that the majority of papers considered real study cases in the construction and validation of the mathematical model. The second most popular domain was noted to be uncertain optimization models, followed by literature reviews. And this leaves the least popular domain for CLSCs to be game-theoretic models. However, it was observed that uncertain optimization models are becoming more common in recent papers and that can help foretell the future direction of CLSC models.

The most popular source of uncertainty

Based on the previous analysis, demand was shown to be most popular source of uncertainty in CLSC. That is mainly because in models where multiple sources of uncertainty were included, it was observed that demand was always considered. Some authors also have considered uncertain return in their mathematical models. As mentioned earlier, as uncertain optimization models become more popular; models are going to consider new sources of uncertainty that would improve the accuracy of the models yet increase their complexity.

The most popular technique

We observed that mixed-integer linear programming is by far the most popular technique. This is mainly because fixed and variable costs can be modeled by binary and nonnegative variables, respectively. In addition, most of the authors considered hybrid techniques in solving their models. This was usually done by combining MILP technique with other techniques (e.g. Fuzzy programing, robust optimization, genetic algorithms, etc…). Another interesting observation is that the complexity of the model is negatively correlated to the complexity of the technique. That is when the modeling is simple, techniques are complicated (hybrid techniques) and when the modeling is complicated, the models usually are solved by commercial software. It is valuable to develop complex models with appropriate solution approaches.

The most popular multi-objective technique

The most popular primary objective function in CLSC multi-objective models is optimization of the total revenue, whether that is by minimizing the total cost of the supply chain network or by maximizing the total sales profit. A lot of focus is being directed towards environmental objectives in recent papers and hence a rise in objective functions related to maximizing greenness or minimizing the environmental impact can be observed. In addition, it can be noted that the majority of multi-objective models in the reviewed CLSC papers have been solved by simple techniques such as weighted-sums method. It is necessary to develop other solution approaches for multi-objective models such as Evolutionary Algorithms. We also observe that a few of authors have developed goal programming models for CLSC networks (e.g. Pati et al. (2008), Selim and Ozkarahan (2006), Gupta and Evans (2009). It is expected that more goal programming CLSC models will be developed in future.

The most popular applications

The literature has been categorized in Table 9 based on two main categories: numerical example and case study (real data). Besides, we have highlighted the application of the models. It can be seen that several authors have utilized test problems and they have compared the results. In some of those papers, test problems have been produced by uniform distributions. It was observed that in papers that are focused on green CLSCs the study cases used were from the electronics industry.

Table 9. Applications of the models

	Application	References
Numerical example	Battery manufacturer	Lashkari and Zhang (2014), Tosarkani and Amin (2019)
	Computer manufacturer	Sheu et al. (2005), Amin and Zhang (2011), Amin and Zhang (2012), Amin and Zhang (2013a)
	Copier remanufacturing	Krikke (2011), Amin and Zhang (2013b), Amin and Zhang (2014)
	Electrical and electronic equipment	Listeş (2007), Gupta and Evans (2009), Xanthopoulos and Iakovou (2009), Alumur et al. (2012), Dat et al. (2012)
	Online sales	Min et al. (2006a), Min et al. (2006b)
	Paper recycling	Kara and Onut (2010)
	Steel recycling	Vahdani et al. (2012a) , Vahdani et al. (2012b) , Vahdani et al. (2013a)
	Test problems	Beamon and Fernandes (2004), Inderfurth (2005), Kim et al. (2006), Lieckens and Vandaele (2007), Lu and Bostel (2007), Üster et al. (2007), Vlachos et al. (2007) , Chung et al. (2008), Demirel and Gökçen (2008), Selim and Ozkarahan (2006), Zhou and Wang (2008), Francas and Minner (2009), Ketzenberg (2009), Lee and Dong (2009), Lee et al. (2009), Mutha and Pokharel (2009), Pan et al. (2009), Pishvaee et al. (2009a), Easwaran and Üster (2010), El-Sayed et al. (2010), Pishvaee et al. (2010), Pishvaee and Torabi (2010) , Pishvaee et al. (2009b), Qin and Ji (2010), Shi et al. (2010), Wang and Hsu (2010a), Wang and Hsu (2010b), Yuan and Gao (2009), Georgiadis et al. (2011), Kumar and Chan (2011), Paksoy et al. (2011), Pishvaee et al. (2011), Rouf and Zhang (2011), Shi et al. (2011a), Shi et al. (2011b), Abdallah et al. (2011), Das and Chowdhury (2012), Kannan et al. (2012), Mitra (2012), Özkır and Başlıgil (2012), Hasani et al. (2012), Zhang et al. (2012), Özkır and Başlıgil (2013), Ramezani et al. (2013), Özceylan and Paksoy (2013a), Eskandarpour et al. (2013), Keyvanshokooh et al. (2013), Soleimani et al. (2013b), Özceylan et al. (2014), Diabat et al. (2015), Ramezani et al. (2014a), Ramezani et al. (2012), Vahdani et al. (2013b), Wang and Huang (2013), Demirel et al. (2014), Hatefi and Jolai (2014), Özceylan and Paksoy (2013b), Ramezani et al. (2014b), Soleimani et al. (2013a), Jindal and Sangwan (2013), Zeballos et al. (2014), Huang and Wang (2017), Kim et al. (2018), Rad and Nahavandi (2018), Rezaee et al. (2016), Tokhmehchi et al. (2015), Tosarkani and Amin (2018a), Tosarkani and Amin (2018b), Tosarkani et al. (2019)
	Third party logistics	Ko and Evans (2007), Du and Evans (2008), Min and Ko (2008)
	Waste	Tang et al. (2008), Zhang et al. (2011)
	Bread-producing company	Mirakhorli (2013)
Case study	Aluminum engine manufacturer	Lashkari and Duan (2007)
	Battery manufacturer	Kannan et al. (2010), Sasikumar and Haq (2011), Sherif et al. (2019), Tosarkani and Amin (2019)
	Beer Industry	Kai et al. (2016)

	Bottled water Industry	Papen and Amin (2018)
	Cash supply chain	Lundin (2012)
	Cell phone manufacturer	Jayaraman (2006)
	Computer manufacturer	Ahluwalia and Nema (2006)
	Copier remanufacturing and paper recycling	Fleischmann et al. (2009), Salema et al. (2006)
	Dairy products	Yavari and Geraeli (2019)
	Electrical and electronic equipment	Jayaraman et al. (1999), Sharma et al. (2007), Zuidwijk and Krikke (2008), Neto et al. (2009), Achillas et al. (2010), Gomes et al. (2011), Assavapokee and Wongthatsanekorn (2012), Talaei et al. (2016)
	End-of-life vehicles	Schultmann et al. (2006), Cruz-Rivera and Ertel (2009)
	Gardening Industry	Roghanian and Cheraghalipour (2019)
	Glass company	Salema et al. (2010), Zeballos et al. (2012), Devika et al. (2014), Pourjavad and Mayorga (2018)
	Hazardous waste management	Hu et al. (2012), Sheu (2007)
	Iron and Steel Industry	Vahdani and Mohammadi (2015)
	Solid waste	Li et al. (2008)
	Lead-acid battery automotive industry	Fazli-Khalaf et al. (2017)
	Nuclear power	Sheu (2008)
	Office document company	Salema et al. (2007)
	Paper recyclers	Pati et al. (2008)
	Printers/photocopier manufacturers	Lee and Chan (2009)
	Recycling Cartridges	Chen et al. (2014)
	Tire manufacturer	Sasikumar et al. (2010), Amin et al. (2017), Ramezani and Jafari (2018)
	Tire manufacturer, plastic goods manufacturer	Kannan et al. (2008)
	Zinc industry	Fröhling et al. (2010)
	Carbon footprint	Fahimnia et al. (2013)
	European supply chain	Cardoso et al. (2013)
	Mobile phone industry	Ahmadi and Amin (2019)

The list of journals

The papers have been categorized based on the names of journals and domains in Table 10. "*European Journal of Operational Research*" has published more papers rather than others. The Table is helpful for authors to identify which journals are more appropriate to submit their articles.

Table 10. List of journals

	Number of articles				
Journal	LR	DO	UO	GT	Total
4OR				1	1
Applied Mathematical Modelling		4	7	3	14
Applied Soft Computing		1			1
Computers & Chemical Engineering			3		3
Computers & Industrial Engineering	2	5	2	1	10
Computers & Operations Research		9	4	1	14
Decision Sciences	1				1
Engineering Optimization		2	1		3
Environmental Modeling & Assessment			1		1
Expert Systems with Applications		2	5		7
European Journal of Operational Research	2	9	5	5	21
Flexible Services and Manufacturing Journal	1				1
Fuzzy Sets and Systems			1		1
Human and Ecological Risk Assessment: An International Journal			1		1
IFAC-PapersOnLine	1				1
IIE Transactions		1			1
International Journal of Business Performance and Supply Chain Modelling	1		1		2
International Journal of Engineering Research in Africa		1			1
International Journal of Operational Research		1	1		2
International Journal of Management and Enterprise Development	1				1
International Journal of Management Concepts and Philosophy		1			1
International Journal of Management Science and Engineering Management		1			1
International Journal of Physical Distribution & Logistics Management	1		1		2
International Journal of Procurement Management				1	1
International Journal of Productivity and Quality Management		1			1
International Journal of Production Economics	3	5	2	3	13
International Journal of Production Research	3	7	8	3	21
International Journal of Services and Operations Management	1				1
International Journal of Sustainable Engineering	3		1		4
Journal of Business Economics	1				1
Journal of Cleaner Production	6	3	7	3	19
Journal of Environmental Management	1		2		3
Journal of Industrial Ecology	1				1
Journal of Industrial Engineering International		1			1
Journal of Remanufacturing		1			1
Journal of Manufacturing Systems	1	1	1	1	4
Journal of Operations Management	1			1	2
Journal of Operational Research	1				1
Journal of the Operational Research Society		2			2
Journal of Systems Science and Systems Engineering			1		1
Journal of Transportation Systems Engineering and Information Technology		1			1
Knowledge-Based Systems			1		1
Management Research Review	1				1
Management Science				3	3
Mathematical and Computer Modelling		1			1
Mathematical Problems in Engineering		1			1
Naval Research Logistics		1			1

Networks and Spatial Economics			1		1
Neural Computing and Applications				1	1
Omega		2	2	1	5
Operations and Supply Chain Management: An International Journal		1			1
Operations Research	1				1
Production and Operations Management		1		1	2
Production Planning & Control		1	1		2
Resources, Conservation and Recycling	4	2	1		7
Robotics and Computer-Integrated Manufacturing			1		1
Sustainability		2			2
The International Journal of Advanced Manufacturing Technology		5	3		8
Transportation Research Part E: Logistics and Transportation Review		5	2	4	11
Waste Management		3			3
Waste Management & Research		1			1
other	1	1			
Total	38	86	68	33	225

Distribution of articles

The literature has been classified based on four domains and year in Table 11. As we mentioned before, we examine the journal publications from 1997 to 2020.

Table 11. Distribution of journal articles

	Number of articles				
Year	LR	DO	UO	GT	Total
1997	1				1
1998					0
1999	1	1			2
2000					0
2001					0
2002		1			1
2003					0
2004		1		1	2
2005		1	1	2	4
2006		7	1		8
2007	1	6	4	2	13
2008	3	10	1	2	16
2009	5	11	4	2	22
2010	2	8	6		16
2011	1	5	8	2	16
2012	3	8	7	2	20
2013	2	5	12	6	25
2014		5	6	4	15
2015	4	3	1	2	10
2016	3	3	3	1	10
2017	5		3	1	9
2018	6	7	5	2	20
2019		4	6	4	14
2020	1				1
Total	38	86	68	33	225

Conclusions and future research

In this paper, the literature of CLSC was classified into four categories: literature reviews, deterministic optimization models, uncertain optimization models, and game-theoretic models. Then, the literature has been analysed based on operations research techniques. Finally, observations and recommendations were provided.

There are several future works in the area of CLSC networks. Some of them are:

(i) There are numerous types of costs in RL and CLSC (e.g. transportation, handling, inventory, quality, sorting, collection, repackaging). However, in most of the models, only few of the costs have been taken into account. As a future research, authors may consider those costs together in the mathematical models.

(ii) Multi-period inventory management parameters were not considered in most of CLSC models. It is valuable to develop multi-period (dynamic) mathematical models.

(iii) Especially for products with short life cycle, the price of reused products in CLSC depends on many factors like remanufacturing process, demand, and environmental concerns. Future research can include CLSC configuration with considering price of reused products as a decision variable.

(iv) Quality of returned products is often overlooked. It is necessary to develop appropriate models and solution approaches to consider quality of all types of returns in CLSC networks.

(v) The complexity of networks leads to large and complex mathematical models that might require a lot of time to solve or even be unsolvable by commercial softwares such as GAMS and CPLEX. Although some authors have utilized Genetic Algorithm previously, more heuristic and meta-heuristics algorithms should be developed to address complex models.

(vi) Due to environmental concern, other than minimizing the total cost (transportation, holding, operation costs, etc.) in a CLSC network; it is also necessary to optimize environmental factors such as waste and recycling. As a result, more multi-objective models and appropriate solution approaches should be developed.

(vii) In CLSC mathematical models, some parameters such as cost, demand, and return are not deterministic. Therefore, some sources of uncertainty should be considered simultaneously. A few authors have considered three or more sources of uncertainty at the same time.

(viii) There are several future avenues for the applications of game theory in CLSC networks particularly multi-echelon networks. Game-theoretic models can help researchers to model competition and coordination between the members of CLSCs.

(ix) Only a few models have considered multi-objective CLSC models under uncertainty in real cases. It is useful to develop multi-objective models integrated with uncertain parameters and applying them in case-studies.

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